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THE AMERICAN

METEOROLOGICAL JOURNAL.

VOL. IX. BOSTON, MASS., AUGUST, 1892. No. 4.

SYNOPTICAL SKETCH OF THE PROGRESS OF METEOROLOGY IN THE UNITED STATES.*

LIEUT. W. A. GLASSFORD, SIGNAL CORPS, U. S. ARMY.

THIS report marking the close of the performance of meteorological duties by the Signal Corps of the Army, it has seemed a proper occasion for the presentation of a brief synopsis of the progress of meteorology in the United States. The following paper has been prepared, not as an exhaustive history but to present in a summary way the several periods of the study of this science in this country, which now is foremost in the practical application of meteorology, and to show the development of the system from obscure beginnings to its present position as a highly organized department of the Government.

The initial point of meteorology as a physical science is determined by the invention of its essential instruments, the barometer and the comparable thermometer. Before these discoveries there existed only desultory observation of the weather, unrecorded save in the folk-lore of unskilled people, available for future guidance only as weather proverbs, shepherds' calendars, and the like; yet this loose and fallacious meteorology took such a strong hold upon the popular mind that its proverbs still remain in common use, and its irrational predictions have not entirely vanished from popular almanacs. The study of the weather was not only popular in the sense that it was a favorite pursuit of the people, but it possessed sufficient inherent inter-

* Reprinted from the Annual Report of the Chief Signal Officer for 1891, Appendix 8.

est to claim the attention of men of science as soon as they found themselves in possession of an instrument of precision with which to prosecute their researches.

The first datum point was Torricelli's discovery of the mercurial barometer, in 1645, which was more prominently brought to notice as the instrument of atmospheric measurement by the experiments of Pascal, in 1648. The suggestions made by Pascal were first exhaustively put into practice by Boyle, in 1659–1660, who is therefore entitled to rank as the first student of scientific meteorology. The institution of the Royal Society of England provided a permanent record of scientific labor, and its philosophical transactions from the beginning contain many notices of weather study by the aid of the barometer. As early as 1684 Plot and Lister, in the *Philosophical Transactions*, expressed their hope of utilizing the new instrument for the purpose of predicting the weather, an object which dropped from sight during a long succession of years.

The second datum point, and the one which marked the full establishment of the science, was the general distribution, in 1720, of the first comparable thermometer with Roemer's scale, which bears the name of its manufacturer, Fahrenheit. Within three years the Royal Society, still maintaining its activity in the prosecution of meteorological research, issued to the world Dr. James Jurin's scheme of an association for forming meteorological diaries. This step established meteorology of record, and Jurin has claim to be regarded as the father of modern statistical meteorology. Even earlier than this is found the first attempt at meteorological record in the pre-instrumental period. Walter Merle, fellow of Merton College, Oxon., England, maintained a daily record of the weather for the seven years 1337–1344. Quite recently this record has been brought to light in the Bodleian library — ten skins of vellum written upon in contracted Latin. It is now in process of fac-simile reproduction and translation, interesting to the curious as the earliest muniment of the science.

These labors of the physicists of the Royal Society possess a direct and intimate relation to the meteorological study of the United States. One of Dr. Jurin's circulars found its way to Charleston, S. C., where Dr. Lining in 1738 began to maintain a record of temperature and precipitation, which he reported to

the Royal Society. American interest in the science was not confined to mere following out the plans of the English investigators, for in 1728 Isaac Greenwood, professor of mathematics in Harvard College, presented a form for meteorological observations at sea, thus by more than a century anticipating in a way the efforts of Lieut. Maury, assigning as a reason for his suggested plan that marine observations "already are by far more numerous than what were ever made ashore, or, indeed, what can be expected thence for some ages to come."

The Charleston observations were followed by several other series of greater or less extent and completeness in different parts of the country, which, slowly increasing in number, prepared the way for the systematic collection of climatic data. It may be not without interest to present a list of these precursors of the modern system, with the date at which observations began: —

For temperature:

Charleston, S. C.	1738
Cambridge, Mass.	1742
Philadelphia, Pa.	1748
Williamsburg, Va.	1760
Bradford, Mass.	1772
New Haven, Conn.	1778
New York	1782
Salem, Mass.	1786
Fort Washington, Ohio	1790
Albany, N. Y.	1795
Andover, Mass.	1798
Natchez, Miss.	1799
Burlington, Vt.	1803
Smithfield, R. I.	1806
Cincinnati, Ohio	1806
Mason, N. H.	1806
Boston, Mass.	1806
Concord, Mass.	1806

For temperature — Continued.

Deerfield, Mass.	1806
Newburyport, Mass.	1806
New Orleans, La.	1807
Brunswick, Me.	1807
Castine, Me.	1811
New Bedford, Mass.	1812

For precipitation:

Charleston, S. C.	1738
Bradford, Mass.	1772
Williamsburg, Va.	1772
Cambridge, Mass.	1784
Morrisville, Pa.	1790
Charlestown, Mass.	1792
Stow, Mass.	1795
Natchez, Miss.	1799
New Haven, Conn.	1804
Monroe, La.	1808
New Bedford, Mass.	1814

These several series of observations were the outgrowth of private interest, which often flagged in the absence of any directing influence; they were irregular in most cases; they were printed in publications not generally accessible, or, remaining in manuscript, were exposed to the catastrophes which await written papers not preserved as public records. The time was ripe for some enthusiast who, by representing a central and

directing agency, should keep alive the interest in meteorological record and secure the preservation of the results.

This enthusiast came forward in the person of Josiah Meigs, commissioner of the General Land Office. He marks the dividing line between the vague efforts of the observers of the eighteenth century and that long period of observation and record which must be regarded as the first era of systematic meteorology in the United States.

Meigs was a man well equipped for the purpose which he set before himself in the administration of his office. Trained in the rigid discipline of the Yale College of the period, he served that institution as a tutor in natural philosophy and later was called to the chair of the same department. His interest in meteorology was displayed during his residence in Bermuda, from 1789 to 1794, during which period he made observations on the meteorology of the islands, which he communicated to the Royal Society. His life was one of great hardship and poverty, which he suffered for the possession of political convictions unpopular in the surroundings where his lot was cast. It resulted that he was unable to give to meteorology that administrative attention which was his purpose until his appointment to the commissionership of the General Land Office placed him in easy circumstances for the first time in his life.

On the last day of January, 1817, he wrote an influential member of Congress suggesting the passage of a resolution to provide for the keeping of meteorological registers at each of the land offices, and that the observations should be returned each month to the General Land Office. His plan contemplated the issue to each land office of the requisite instruments for observations of temperature, pressure, rain, and wind. He failed to secure the sanction of Congress, but issued a circular, April 29, 1817, in which he asked the several registers, his subordinates, to take regularly certain meteorological observations, for which he supplied blank forms. Purely voluntary as the service was, and without any financial support, it fell somewhat short of the plan suggested to Congress, for barometers were both rare and expensive. The blanks were ruled for a tri-daily observation of temperature, wind, and weather, together with a column of remarks of a general and phenological character. The system attained considerable proportions from the beginning, but it

seems to have lapsed on the death of the founder, in 1822. The records have never been collated, and are believed to be preserved in bulk in the possession of the American Institute of New York. It is of interest to note that Meigs, from comparison of the voluntary reports sent him, was able to recognize the area of several cold waves, even though the insufficiency of his information precluded the discovery of their motion in progression.

The next system of observations was established by the surgeon-general of the Army, and has been maintained as a system to the present day, although subject to various modifications as the conditions of meteorological study were altered. The office of the surgeon-general was created in 1818, and Dr. Lovell was at once appointed. His first instructions to hospital and post surgeons directed them to keep a diary of the weather. The earliest registers filed under this system begin with January, 1819. For the first few years the only instruments furnished were the thermometer and the wind vane. In 1836 the rain-gauge was added to the equipment, and in 1841 barometers and hygrometers were supplied to a few stations by way of experiment. In 1843 a new and more complete system was put in operation, and the military posts and hospitals were called upon to maintain a record of observations of the barometer, attached thermometer, detached thermometer, rain-gauge, wet-bulb thermometer, and to note the clearness of the sky, the direction and force of the wind, and the direction and velocity of cloud movements. The observations of the wet-bulb thermometer were discontinued in 1849, and renewed in 1855 with a better instrument. The office transcripts of the original returns of the observing surgeons have been transferred to the Signal Service, where they are now preserved. The larger portion of these reports also exists in printed form. The results of the observations during 1820 and 1821 were published at the end of each year. Thereafter the results were grouped by convenient periods in the "Army Meteorological Register," of which the first volume, published in 1826, contained the observations for the years 1822 to 1825, inclusive; the second volume, issued in 1840, contained the results for the years 1826 to 1830, and in an appendix reprinted the first volume; in 1851 the third volume was issued, with the tabulated observations from 1830 to 1842, and in 1855

the fourth volume carried the tables from 1843 to the end of 1854. This was the final meteorological publication of the surgeon-general's office. The records after 1854 were handed over to the Smithsonian Institution, and in due time were transferred to the Signal Service.

Within a few years the subject, which was too unimportant for Congress to consider in 1817, had attained a recognized position as entitled to public support. In 1825, but eight years after Meigs's ineffectual plea, the University regents of New York directed that each of the academies under their jurisdiction should be furnished with a thermometer and a rain-gauge, and that the diligent report of observations should be an essential condition of their receipt of State funds. Further instructions from time to time directed observations of the wind and a variety of miscellaneous occurrences, considerable attention being directed upon phenological phenomena. The observations began in 1826 and were continued more or less completely to 1850. During this period sixty-two academies reported observations, of which three were complete for the whole term, and only three failed to record the precipitation. In 1849 the Legislature made an appropriation for the purchase of improved instruments in order to conform the State system of observations with the more comprehensive system recently instituted by the Smithsonian Institution; a small sum was appropriated for salary of observers. The instruments provided by this appropriation were a mountain barometer, thermometer, rain and snow gauge, wind vane, and to a few stations wet and dry bulb thermometers. The system came into operation at the end of 1850, and thirty-five academies began the observations. From the first the humidity observations were a failure, owing to confusion of reduction tables and thermometric scales. In 1863 the Legislature failed to make the small salary appropriation, and from that time the system rapidly declined, both from that cause and from the greater weight of the Smithsonian observations covering the same ground. The reports of these observations were published in the annual reports of the regents from 1826 onward. In 1855 the observations from 1826 to 1850 were collated and published, and in 1872 appeared a similar collation of the second system of observations, from 1850 to 1863.

Pennsylvania was the next to feel the influence of the new

study. In 1834 was formed a joint meteorological committee of the American Philosophical Society and the Franklin Institute, of which James P. Espy was chairman and A. D. Bache a leading member. A circular was issued by the joint committee in the same year giving directions to observers. At this period less attention was paid to securing continuous record than to gathering information concerning individual storms which had attracted the attention of the committee. Something was accomplished by this method, but it was evidently not the method for systematic research. In 1837, however, the Legislature appropriated four thousand dollars for the advancement of meteorology and intrusted its expenditure to the joint committee. Out of these funds there were authorized to be purchased for each county in the State a barometer, two common thermometers, a self-registering thermometer, and a rain-gauge. This State grant in aid established in the year 1839, when it became available, twenty-two stations maintaining a record of temperature, to which six were added in the years next following; the stations recording precipitation under this system were but seven. Most of the records were brief and many were irregularly interrupted; the system died out in less than ten years, and its records found a permanent place in the publications of the two societies which joined in the committee of administration.

The Secretary of War in 1839 solicited from J. N. Nicollet an essay on Meteorological Observations. This was published by the War Department early in the same year as a circular of the Bureau of Topographical Engineers.

The prefatory note stated that the essay had been printed for distribution to those officers whose duty it might be to make observations on the phenomena of which it treats, and for the benefit of others whose tastes and situations might induce them voluntarily to aid the cause of science and the useful arts. It was noted that the observations made by officers of the corps were to be forwarded regularly, and that those made by voluntary observers would be received with pleasure. Despite this promise of meteorological activity, nothing seems to have been done by the engineers for almost twenty years. This corps began the survey of the northern and northwestern lakes in 1841, but meteorological observation in connection therewith received little consideration at first. In 1857 Capt. George

G. Meade in his report recommended the observation of meteorological phenomena over the whole lake region. This recommendation was approved and instruments were ordered in sufficient quantity to equip each station with a barometer, thermometer, psychrometer, rain and wind gauge. Three stations were established on Lake Ontario, four on Lake Erie, five on Lake Huron, three on Lake Michigan, and four on Lake Superior. The observations began July 1, 1859, and were recorded and in some instances discussed in the annual reports of the Survey. As a result of an agreement with the Signal Service the series ended in 1872 as a duty of the Engineer Corps, with the exception of three stations which were kept in operation to 1876.

In the introduction to the last volume of the "Army Meteorological Register" the statement is made that Ohio instituted a State system of weather observation in 1842. No further information is to be found as to the action of the State government, if any; but the statement finds a certain amount of confirmation in the fact that in 1843 five stations of observation were inaugurated in the State. Since very few stations had been opened prior to that date and at no period so many in one year, a certain preconcert is evident.

The Patent Office was the next department of Government to manifest interest in the recording of climatic phenomena. The seeming inconsistency of this with the more legitimate objects of the office disappears when it is remembered that at that time agriculture formed a division of the Patent Office. In the early reports of this office occur brief memoranda of notable weather phenomena which exerted a greater or less influence upon the crops then under investigation. Year by year these memoranda became fuller, and in 1847 they took the form of tabulated data for one or more years from different stations. In 1854 this series of reports contained Blodgett's essay on the "Agricultural Climatology of the United States"; from 1855 to 1859, inclusive, they contained, in five annual instalments, Joseph Henry's contribution, entitled "Meteorology in its Connection with Agriculture." In 1860 the Commissioner of Patents sent to the Senate a volume of results of meteorological observations made under the direction of the Patent Office and the Smithsonian Institution for the years 1854–1859, inclusive.

In 1849 the State of Massachusetts inaugurated a series of observations under State direction, which in the next year was merged in the Smithsonian system.

The Smithsonian Institution in 1849 began its great work in the field of American meteorology along several parallel lines of research, which appear topically as record of observations, publication of material aids to meteorological study, and forecast of approaching weather conditions. As a bureau of record the Institution, under the direction of Joseph Henry, gathered up from all sources past records of observations, assisted the few systems of observations then in existence, and instituted its own system throughout the country. Before this time the records, if published at all, appeared in most cases without corrections or reductions, and very rarely were they discussed. But the Smithsonian was in a better position than any other organization to give the rapidly accumulating data scientific treatment, and for that reason the data of other systems were at first sent to the Institution for examination, as was the case with the Patent Office series, and by natural growth the individuality of the several independent series was, for greater convenience, merged in the Smithsonian. Thus it came about that in 1870 this great institution controlled all the meteorological records of the country.

Next in order of time, the Signal Service in its capacity as a depository of records should be mentioned, but as its meteorological duties were expressly undertaken to facilitate weather predictions, its consideration will be deferred until it naturally arises in that branch of the inquiry.

There yet remains one other series of records to examine — those maintained by the Coast Survey. It has already been shown that Bache was a leading and enthusiastic member of the joint committee which instituted the Pennsylvanian system of observations. That interest he infused into the survey of which he was chief, and the results, though not voluminous, are valuable. In the annual reports of this survey there appeared in three parts, Ferrel's "Meteorological Researches for the Use of the Coast Pilot"; in the report for 1875, Appendix 20, "On the Mechanics and General Motions of the Atmosphere"; in the report for 1878, Appendix 10, "On Cyclones, Tornadoes, and Waterspouts"; in the report for 1881,

Appendix 10, "Barometric Hypsometry, and the Reduction of the Barometer to Sea Level." The Survey's Pacific Coast Pilot contained, in 1879, an appendix in which Dr. William H. Dall collated and reduced all meteorological observations which had been made from the earliest times in Alaska and the Bering Sea region, subjoining to the tabulated data some discussion of the phenomena noticed. The publication is a most important contribution to the knowledge of this remote district of the country.

In passing to the second great period of American meteorology, that in which the skilled labors of the makers of verifiable forecasts have developed practical utility out of the mass of accumulated data, it is of interest to remark that this latest development of modern meteorology was the very first aim of the first students of the aspect of the sky. The folk proverbs are full of predictions of what the weather is to be. No more than forty years from the invention of the barometer the Royal Society was informed in 1685 of the pitch of knowledge to which the learned Dr. Goad, of London, had arrived in predicting the weather. At the same time it was recognized that the results of observations were an essential preliminary, and for two centuries the study of the weather was narrowly restricted to record and the preservation of materials for study.

While systematic meteorology under State aid confined itself most strictly to the sphere of preserving a record of observations, private investigation undertook the study of the physics of the weather with particular reference to the law of storms. Franklin seems to have led this line of research, for he is on record in 1747 as having deduced from such observations as were available the fact that the northeast storms were generated in the southwest. But it was not until the fourth decade of this century that the formative period of American meteorology may be said to have begun.

William C. Redfield was the first in the field. In 1831 he published his conclusions that a storm was a great whirlwind rotating from right to left about an advancing centre. In 1846 he was the first to appreciate the position of cold waves in reference to advancing storm centres.

James P. Espy was contemporary with Redfield. He has been mentioned already as chairman in 1834 of the joint com-

mittee which instituted Pennsylvanian meteorology. The recognition of his theory, which failed in this country, he secured abroad by his paper "On Storms," read before the British Association in 1840. The conclusions at which he finally arrived were that storms sweep across the country from west to east; that they possess a medial axis of low pressure, generally extending north and south, with the central minimum on the middle of the axis; that the winds flow toward the axis from either side, with a tendency towards the centre,

Charles Tracy in 1843 examined the conflict, then at its height, between Redfield and Espy. Although Tracy's paper "On the Rotary Action of Storms" was his single contribution to meteorology, it deserves high place, because it anticipated many of the best results of later investigators.

William Ferrel, since professor of meteorology in the Signal Service, was the first to apply mathematical methods to the solution of meteorological problems, in which he has covered the whole range of mathematical and physical meteorology, with the sole exception of electricity. His explanation of the general planetary circulation of the winds is considered his greatest discovery, and this Newton of meteorology has until lately been connected with the Army Signal Office.

James Henry Coffin is first recorded in meteorology as one of the observers of the academic system of the New York regents in 1839. At a later period he reduced the observations which were published in the great volume of the Patent Office in 1861. His great work is the treatise on the winds.

Elias Loomis was a student at Yale when Redfield's first paper appeared. He held a tutorship in the same college when Espy propounded his rival theory. The consequent discussions he followed with characteristically grave interest, and from that time to the last day of his life meteorology held the first place in his thought and work. In addition to the preparation of the standard text-book of meteorology and the valuable series of contributions, he was the first to form the weather maps now so common. It was in 1842 that the first map appeared with lines of equal pressure and temperature, wind direction, and areas of precipitation.

The telegraph transformed meteorology, made it possible to make daily test of the theories advanced by these physical in-

vestigators, and created the science of forecasting, which from the earliest times had been the aim of all weather watchers.

The first to recognize the great field of practical work just opening was Lieut. Maury, of the National Observatory. He was no novice in meteorological research. In 1833 he had examined into the causation of the prevalent low barometer off Cape Horn; in 1840 he announced his intention to study the storms and winds; and there appeared soon after his "Physical Geography of the Sea" and its Meteorology, while his services to navigation by the wind and current charts can never be too highly estimated. In 1851 he originated the plan of what he named "farmer's meteorology," on the plan of his hydrographic logs, by enlisting the service of farmers throughout the country to report weather observations.

Two years later he assembled a meteorological congress of maritime nations at Brussels, and recommended the institution of a co-ordinated series of international observations by land and sea. In 1855 he addressed many agricultural societies of the South and West on this topic, and urged them to memorialize Congress to establish a central office where weather reports might be digested and telegraphed to all parts of the country, warning farmers of the approach of storms and frosts. Several bills looking toward the accomplishment of this end were presented in Congress in the session of 1857, and favorably mentioned by the Senate Committee on Agriculture in an exhaustive report by Mr. Harlan, Dec. 18, 1856 (Senate Rep. Com. No. 292, Thirty-fourth Congress, Third Session). Other influences prevailed, the bill failed to pass, and before Lieut. Maury could secure the establishment of his system the nation had passed into the turmoil of a civil war.

The Smithsonian Institution early recognized the possibilities of the telegraph, and in 1856 it made practical application of the simultaneous weather reports received by wire, and maintained a daily weather map at the Institution. The first attempt at published prediction seems to have been in 1858; it is found in Prof. Henry's statement to the American Academy that when the map showed rain at Cincinnati in the morning it was considered an indication of rain at Washington in the evening sufficiently trustworthy to warrant postponing the lectures at the Institution. The war interfered with the development of the

plans of Prof. Henry, and when he was about to resume in 1865 the disastrous fire at the Institution crippled the resources at his command.

The idea thus by unfortunate circumstances forced into neglect was revived by Prof. Cleveland Abbe, since and now professor of meteorology, Signal Service, at that time director of the Cincinnati observatory. In 1868 he succeeded in interesting the Chamber of Commerce of that city in the project of daily predictions of the weather, and under its auspices began to issue the "Weather Bulletin of the Cincinnati Observatory," which lasted from September, 1869, to January, 1871, when he was summoned to Washington to assist in the formation of the forecasting service recently assigned to the Signal Corps.

Here begins the long period in which American systematic meteorology has been embodied in the Signal Service.

The initial impulse which led the Federal Government to assume this work of public utility was given by Dr. Increase A. Lapham, of Milwaukee. Having had his attention particularly directed to the destructive gales of Lake Michigan, he had studied the early movements of the storm centres with the result that he convinced himself of the feasibility of predicting their oncoming to the great benefit of lake navigation. In 1869 he was able to convince the National Board of Trade of the value of his suggestion, and in December of the same year he addressed a memorial to Gen. Halbert E. Paine, member of Congress for Milwaukee, setting forth the possibilities of the plan and confirming its commercial importance by a list of 1,914 lake disasters caused by sudden and unannounced storms. Gen. Paine introduced a resolution embodying these suggestions, Dec. 16, 1869, and secured the favorable indorsement of the three great authorities on meteorology, — the Surgeon-General of the Army, the Secretary of the Smithsonian Institution, and Prof. Elias Loomis, — and in addition the assurance of Gen. Myer, Chief Signal Officer, that it was quite possible to report and foreannounce storms by telegraph and signal. The resolution was passed and approved Feb. 9, 1870, and thus was created the Meteorological Bureau of the Signal Corps.

The new service went into operation Nov. 1, 1870, with stations fully established, and has been maintained without interruption. Dr. Lapham was called in frequent consultation

with Gen. Myer in establishing the novel system and was pressed to take the position of senior civil assistant, but he felt physically unable to undertake the arduous duties, and the position was filled by his friend and correspondent Prof. Abbe.

It is seen that the purpose of the Weather Bureau of the Signal Service as originally defined was the warning of storms upon the northern lakes and eastern seaboard. By a natural extension it became a bureau of record as well, for the reports of its special observers were filed in the central office. In 1872 and again in in 1873 its scope was considerably increased by acts of Congress, and in the latter year was instituted the publication of the "Monthly Weather Review," which was the first attempt in this country to present meteorological data to the general attention of students with the least interval after the occurrence of the phenomena discussed. In 1874 the new Bureau had given such satisfactory proof of its success and such promise of its permanence that the Smithsonian Institution transferred to it all the material collected in a long series of years under that system. From that time the Signal Service, in addition to its forecasting functions, has developed into the most comprehensive bureau of record. Its well-ordered files contain almost the entire mass of observations taken from the earliest times, and additions are constantly made.

NOTE ON WINTER THUNDERSTORMS.

PROF. W. M. DAVIS.

DURING a review of the study of thunderstorms several years ago, the results of which were published in this JOURNAL in 1886 (Vol. II., 489–499; III., 40–48, 69–79), I found that observers in Scotland and Iceland had noted the occurrence of thunderstorms in winter chiefly as nocturnal and marine phenomena. Thus Buchan, writing on the diurnal periods of thunderstorms in Scotland (J. Scot. Meteorological Society, V. 1880, 324–329), found that a distinct afternoon maximum appeared for the time of occurrence in the yearly totals, but on taking the northwestern stations alone, that is, those near the Atlantic coast, and counting only the winter storms, a midnight maximum and a noon minimum were found. This

result was confirmed by the observations at Stykkisholm, Iceland, where twenty-two out of the twenty-three thunderstorms that occurred in fourteen years were recorded in the cold months, from October to March, and twenty were heard between sunset and sunrise.

Scott examined the records of thunderstorms reported to the British Meteorological Office from 1866 to 1871 (Q. J., Meteorological Society, I., 1873, 59), and found that most of the stations had maxima in the summer; but that Valencia, on the west coast of Ireland, had a strong winter maximum. The hours of most frequent occurrence are not given.

The abstracts of Mohn's results for Norway, presented in the French *Atlas Météorologique* for various years, state that while the hour of most frequent occurrence for the year is in the afternoon, yet the few storms that occur on the Norwegian coast in the winter appear to be more characteristic of the night than of the day.

Since then I have found the same relation to obtain in our New England thunderstorms, as was shown by various examples given in an account of the Types of New England Weather in the Investigations of our New England Meteorological Society for 1889 (Annals of the Harvard College Observatory, XXI., 1890, 126). It is there stated that our winter thunderstorms show a tendency to more frequent and intense development near the coast than inland, and a preference for evening rather than for afternoon hours; although they are not unknown in the cold season inland and by day. Thus on the evening of Nov. 6, 1886, two thunderstorms occurred within the area of a warm southerly wind — the New England sirocco; their greatest severity being in southeastern Massachusetts between six o'clock and midnight, when they caused heavy rain with many lightning strokes. On March 21–22, 1886, a severe thunderstorm passed over eastern Massachusetts about midnight in another sirocco, the greatest damage reported being at Woburn, a few miles north of Boston, where the water-mains were shattered by a lightning stroke at 12.30 A. M. Finally, on Feb. 17, 1887, a thunderstorm traversed southern New England between 7 P. M. and midnight, with greatest violence near the coast, where several buildings were struck by lightning.

All of these examples abroad and at home are associated with

general cyclonic storms, the lightning flashes and the heavier rain that generally accompanies them being only incidents in a larger storm with an expanded area of cloud and rain. It therefore seems legitimate to conclude that, while thunderstorms are truly less common in winter than in summer, those which then occur are chiefly noted near or on the coast and at night. Whether the preference of winter thunderstorms for night hours is true for continental interiors is not clear; but from the evidence that I now have, it would not appear to be true; whether the conditions of occurrence along the coasts above mentioned may be extended to apply to the northern part of the Atlantic Ocean as well, and then to other oceans, remains to be seen.

Summer thunderstorms are generally regarded as convectional phenomena, and with good reason, in spite of the outrush of the squall-wind from their forward base. The belief in their convectional origin is based on their frequently visible overflow aloft, where the cirro-stratus sheet spreads outward from the cumulus thunder-heads; on their greater frequency in the torrid zone compared to high latitudes, where they are rarer and weaker; on their greater frequency and intensity in our latitudes on land than at sea; and on their common association with that quadrant of cyclonic storms in which a vertical instability might be expected.

The question may then be asked, Does the convectional origin of thunderstorms in summer imply a like origin for thunderstorms in winter, even though they occur then at night; or does the occurrence of winter thunderstorms at night imply that they are phenomena of another class and origin from those of summer? The first conclusion appears to me more probable than the second; for if winter thunderstorms are, like summer thunderstorms, convectional in origin, they should be expected to occur as they do, at night, and not by day. The reasons for this conclusion are as follows:—

Convectional processes, such as those of summer thunderstorms, are believed to depend on a relatively rapid vertical decrease of temperature, or strong vertical temperature gradient. We are accustomed to ascribe this to an increase of temperature in the lower atmosphere and to look for it in the summer and on land; for in summer time, when convectional processes are best developed, it is at the bottom of atmosphere that the

greatest increase of temperature is found. It is chiefly through the intermediate action of the land in absorbing solar energy that the lower air is warmed. As conduction and radiation are the means of giving to the air something of the heat acquired by the ground in summer, it is natural that the lower air should then be warmed more than the upper air; and that at such a season the vertical temperature gradient over the continents should be increased, and all convectional processes strengthened. Not only thunderstorms illustrate this result; it controls many gentler processes, such as the growth of the diurnal but rainless cumulus clouds of fair summer weather; and the increase of the velocity of the surface winds of daytime.

It is, however, manifest that cooling the upper part of the atmosphere would be almost as effective a cause of instability and convection as warming the lower part. The only reason that this process is not generally appealed to is that there is as a rule no sufficient opportunity for its occurrence. The clear pure upper air suffers less change of temperature than the moist or dusty lower air, close to the surface of the ocean or land. There is generally no more effective means of cooling the upper air than of warming it. But under certain special arrangements, it is possible that an instability may be brought about between the air lying on an elevated plateau and that on the surrounding lowlands. This has been recognized by several writers: Köppen has thus contrasted the Bora and the Foehn (Zft. f. Met. XVII., 1882, 467) and F. von Wrangel has given a similar explanation for the Bora, a violent and cold descending wind, of Novorossisk, on the north shore of the Black Sea near the western termination of the Caucasus Mountains. He supposes that the air lying quiet on the plateau becomes excessively cold, so cold that even when its temperature is increased by compression during descent it will reach the lowlands colder than the air that lies on them; and hence that any slight tendency to move the air off of the plateau, such as the approach of an anticyclone, will initiate a motion that will continue until all the cold upper air is drained away (*Ueber die Ursachen der Bora in Noworossisk*, Repert. für Meteorol., V., 1876). Several less pronounced examples of this kind are referred to in an essay, by the writer, on Mountain Meteorology (Appalachia, IV., 1886, 248).

Is it not possible that an effective cooling of the upper air may occur at the upper surface of a cloud stratum, particularly in the winter season, when the nights are long, and when the temperature at lofty elevations is so low that the liberation of latent heat will be comparatively ineffectual in retarding the cooling caused by radiation from the cloud surface?

We know that clouds may intercept much of the intensity of sunshine, or that they may prevent the loss of heat by nocturnal radiation from the earth. They must therefore lose much heat by radiation from their upper surface at night, particularly when the nights are long. It might be objected that the liberation of latent heat, which must accompany the condensation resulting from radiation in the upper part of the cloud sheet, might supply much of the energy lost by radiation, and hence retard the cooling of the cloud surface; but while this is an important process in saturated air of high temperature, such as may occur in summer thunderstorms near their base, it is much less efficacious in saturated air of low temperature, such as must exist at the upper surface of cloud sheets in winter cyclonic storms; the difference between the two cases being dependent on the well-known rapid decrease of capacity for vapor at high temperatures, and the slow decrease at low temperatures. All things considered, it appears permissible to recognize an effective cooling during winter nights at the upper surface of cyclonic cloud sheets.

If the cooling of the upper cloud sheet were the only element in the problem, we ought to find winter thunderstorms as common on land as at sea; but the few observations referred to above contradict this. There must therefore be some other element besides the cooling of the upper-cloud strata, and this may be found in the conservatism of the ocean surface as to loss of temperature in winter. When the cyclonic storms, in which the winter nocturnal thunderstorms are generated, drift from a continent out over an ocean, the opportunity for instability and overturning is increased. The lower air on the sea is much warmer in winter than the lower air over the land at the same latitude; hence the increase in the vertical temperature gradient as a cyclonic storm departs from the cold land area and advances across the comparatively warm ocean; hence also the decrease in the vertical temperature gradient as the cyclonic storm passes from an ocean area upon a continent. If the conservatism of

the sea as to warmth in winter were the only element in the problem, the marine thunderstorms of winter should be as common by day as at night; but if the two elements here considered are regarded as co-operating to determine strong vertical temperature gradients, then the thunderstorms thus generated will be for the most part limited to marine areas and nocturnal hours. Taken all together, there seems to be some reason for regarding the winter nocturnal and marine thunderstorms as in good part of convectional origin.

The objection may be urged that if the upper air descended in large volume, a clear space should be formed in the cyclonic cloud sheet; and to this I can only answer that the suggested process must not be supposed to go so far as that. The cloud sheet is thick and heavy; the ascending movements, that must be associated with the supposed descent, will re-enforce the cloud mass. Still, it should not be overlooked that a strong descent of cloudy, top-heavy air might produce a break in the general cloud sheet. Is there any record of such an occurrence in this connection?

The speculative quality of such a suggestion as this should be carefully borne in mind; for it is plain enough that we have no direct observations on which to base the various suppositions as to vertical instability during winter thunderstorms. Indeed, the case is characteristic of the method, distasteful to some students of our science, by which explanation is searched for before *all* the facts on which it depends are determined by observation. Theoretical meteorology would indeed have long to wait if its advance were not begun until all the facts concerning the atmosphere were determined by observation. The essence of theorizing consists in surmising unobserved facts and combining them with facts determined by observation in such a way that some understanding of possible processes is gained. The danger in theorizing seems to me to lie in the memorizing of its results rather than of its arguments; and in confusing its suggestions with facts of observation, as having the same order of verity. If the two classes of considerations are carefully separated, and if the reasons for entertaining a theory are always held in the mind along with the provisional conclusions to which the theory leads, then theorizing is a profitable exercise. I do not wish to assert that the nocturnal thunderstorms of winter on the ocean

are undeniably of convectional origin, but it seems to me that they may be provisionally regarded as chiefly dependent on a pronounced vertical temperature gradient, determined in part by the cooling of the upper air about the lofty cloud stratum of cyclonic storms by radiation, and in part by the maintenance of relatively high temperatures in the lower air by the conservative waters of the ocean.

This explanation seems so obvious that I have hesitated to publish a note upon it, hoping to have leisure to search for its previous statement; but that leisure does not arrive, and, without waiting for it longer, I offer the suggestion for the consideration of those who find entertainment in theoretical explanations of observed phenomena.

HARVARD COLLEGE, June, 1892.

PAPERS FROM THE LABORATORY OF PHYSICAL GEOGRAPHY OF HARVARD COLLEGE.

No. 7. — OBJECTIONS TO FAYE'S THEORY OF CYCLONES.

WM. C. MOORE.

Introduction.
Faye's theory.
Generally accepted theory.
Discussion of different points in Faye's theory :—
Inflow in upper part of storm *v.* observed motions of cirrus clouds.
Outflow at bottom *v.* observed facts of inflow.
Descending whirl. Evidences of ascent in clouds and rain.
Trajectory.
Gyrations.
Statement that storms have not been observed to develop gradually. Evidence to the contrary.
Conclusion.

Introduction. — At the conclusion of M. Faye's series of articles lately published in the "American Meteorological Journal"* the editor expressed the opinion that any discussion of M. Faye's theory would not be unwelcome to its distinguished author.

The writer, encouraged by this, presents the following article in the attempt to show why the generally accepted interpretation of facts and the theories of explanation seem to him preferable to those brought forward by M. Faye.

* Vol. VI., 1889–90, 289, 355, 404, 493.

Faye's Theory.—Let us first examine Faye's theory. He finds two kinds of low-pressure areas, one of which is short-lived, and has no onward movement, and is due to a local rarefaction of the atmosphere, and another which has a longer life and a progressive movement. The latter, he says, is the true cyclone, and is formed by the eddies of the upper current of the atmosphere. In this class he includes all vigorous travelling cyclones. The first kind he briefly dismisses, even without telling us how they can be distinguished from the others when they first appear. Shall we say that all those low-pressure areas which appear on the map one day and, failing to gather energy, have disappeared by the next, belong to the first class, and that those which, steadily increasing in strength, begin to move onward, are due to an entirely different cause? What evidence do we have that such is the case? He assumes that the second kind of cyclones is different from the first, because they travel; convectional whirls, he thinks, would not travel; yet the convectional whirls of the desert travel as soon as they are fully formed.

The eddies of the upper current of the atmosphere mentioned above as the cause of the true cyclone are produced, he says, in a manner analogous to that in which whirls are produced in rivers. He conceives cyclones to be great whirls of air, *descending* around a vertical axis, from the upper currents of the atmosphere where they originate. The whirling motion is set up by the inequalities in the velocity of different parts of the upper current, and the onward progressive movement is due to the flowing of the whole current in which the whirl is formed. The unequal currents are formed in the great body of air flowing from the equator by the lack of symmetry of the terrestrial surface.

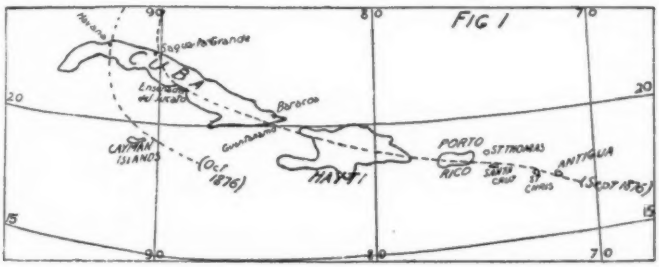
It is pertinent to observe here that Faye accepts the difference of temperature between the equator and poles as a cause for a general convectional circulation of the atmosphere, but does not consider local differences of temperature an effective cause in producing cyclones, although in a medium so mobile as air a slight inequality in temperature, and hence in pressure, is sufficient to cause motion.

Generally Accepted Theory.— The theory which Faye opposes is the one now commonly accepted, viz., that tropical cyclones

are formed by a local excess of temperature or difference of pressure, causing an essentially convectional motion ; the accompanying gyrations being due to the earth's rotation, and the progression due principally to the general movement of the atmosphere and perhaps to the inequalities in the amount of rainfall on different sides of the storm centre. The cyclones of the temperate latitude are more or less deformed, having unlike temperatures and weather on different sides, but are otherwise the same as the tropical cyclones, in possessing a whirling inflow below and outflow aloft. For our present purpose it is not necessary to consider whether these storms are self-driving, as suggested by the convectional theory, or whether they are driven by some outside force. Faye says this theory fails to account for the gyratory and onward movement of cyclones ; for he believes that " the feeble and slow diurnal rotation of the earth is incapable of producing the large and powerful gyrations of storms."

Motions of Cirrus Clouds.— In the discussion of Faye's theory, the first point we consider is in regard to the motion of the cirrus clouds. As a consequence of his theory, the cirrus clouds near the centre of the storm ought to converge. Let us see why. The cirrus clouds are borne along by the current in which the whirl originates, the direction of these clouds indicating the direction of the current, and that part of the cirrus clouds in the vicinity of the whirl will be drawn towards the centre and down, and hence have an inflowing motion. Of course the clouds beyond the influence of the whirl, in the front and rear, and on both sides, may still have the same general direction as the current. Let us examine some of the recorded observations of tropical storms as reported by Viñes in his work entitled " Apuntes relativos a los huracanes de las Antillas," to see if these conditions are found to exist. In September, 1876, a cyclonic storm approached the Windward Islands on the 12th from the southeast or east-southeast, being first felt at Antigua. On the evening of the 12th the vortex arrived at the island of St. Christopher. It then passed between Santa Cruz and St. Thomas and across the island of Porto Rico. From thence it crossed the island of Hayti and reached Cuba between Baracoa and Guantanamo. The left part of the central calm touched the last-named place on the night of the 14th. During that

night and the morning of the 15th it ran in about the same direction along the eastern part of the island, and reached the sea at Ensenada del Jucaro about noon on the 15th, where it began to recurve towards the northwest and north across the island and left the northern coast near Sagua la Grande, where the central calm was felt at midnight between the 15th and 16th.



At the time this storm was central over Ensenada del Jucaro cirrus clouds were observed at Havana coming from S. E. ¼ E. After the storm had passed over Cuba, and when its centre was about two hundred and seventy miles to the northeast of Havana, cirrus clouds were observed at that place coming from the northeast. This storm did not pass centrally over Havana but was deflected toward the north at about latitude twenty-two degrees N. Evidently, then, here is a case in which the conditions do not agree with those which are demanded by Faye's theory, for the cirrus clouds which appeared at Havana from S. E. ¼ E. did not have the same direction as the trajectory of the storm, nor the direction which they ought to have if the upper currents moved in toward the centre. On the contrary, their direction was what we should expect it to be if we consider the upper currents of air as moving out from the centre. Notice, also, that while this storm was pursuing a general northerly direction just after leaving the island of Cuba, the cirrus clouds, which were then visible at Havana, extended from the northeast towards that place, thus giving further evidence of the existence of outflowing currents in the upper regions of the atmosphere.

The storm of the following month furnishes additional evidence. On Oct. 17, 1876, a cyclone was reported in the vicinity

of the Cayman Islands, south of Cuba. On the 18th it struck the western half of Cuba and passed centrally over Havana. The storm had already recurved before reaching Cuba, and its path over the island was in a northerly direction; after leaving Cuba its direction became northeasterly. At the time when the centre was still some three hundred miles away the appearance of cirrus clouds from the south-southeast and southeast was observed at Havana. After the passage of the centre, and before all the nimbus clouds had gone, the cirro-stratus clouds appeared from the northeast. The same argument can be drawn from these observations as in the previous case.

The observations quoted above were of *plumiform* cirrus clouds, which are to be distinguished from the *filiform* cirrus clouds which Viñes ascribes to the lofty anti-trades. The filiform clouds are parallel and even, indicating a broad, steady movement. They cross the heavens in fixed directions and correspond to the general motions of the atmosphere. These filiform clouds are the ones in which Faye says these whirls are formed. Viñes recognizes these clouds, and shows them not to be the kind which is associated with these tropical storms. The plumiform clouds appear to be spreading across the sky; this radiation or divergence is in part real, and in part due to perspective. The notable divergence of plumes which surrounds the cirro-stratus seems to indicate subdivisions, ramifications, and attenuations of the outer currents; while their departure from straight lines, doubling and curving at the outer end, indicates the resistance which these currents, weak and attenuated in their final ramifications, meet in the medium which they traverse. "It has been observed that the cirro-stratus clouds place themselves so that their focus of radiation or divergence corresponds nearly with the bearing of the centre. This is considered a very good indication, and is fortified by numerous observations." * Viñes, whose residence in Havana has given him great opportunity for studying these storms, states that, after a careful examination of the plumiform cirrus clouds, he concludes that they are the upper outflow corresponding to the lower inflow, and that they are the result of the

* Practical Hints in Regard to West Indian Hurricanes, pp. 6 and 7.

carrying up of vapor which was not already condensed at the lower levels.

It is to be regretted that there are no published observations on the motions of cirrus clouds in the Bay of Bengal cyclones. Among the *Indian Meteorological Memoirs* the statement is made that the "cloud movement which precedes and accompanies the storms is exceedingly complicated and indicates violent and rapid action and motion in the higher atmospheric strata. Observations on this point are yet much needed and will probably throw very considerable light on the character of atmospheric action in the upper strata."

The storms of September and October, 1876, described above, are especially important, because they come from a region which is peculiarly subject to devastating cyclones or hurricanes, and because these storms have much of the regularity of oceanic cyclones, and yet the observations can be made with all the facilities for accurate observation afforded by land stations. They were true tropical cyclones. In the tropical cyclone the various phenomena are almost symmetrically arranged about the central area. As these cyclones leave the tropics they become more and more deformed and lose their symmetry. Abercromby says: "Cirrus and halo appear all round a tropical cyclone, while they are never seen in the rear of a European storm." * This is characteristic of the storms of the middle latitudes.

Having examined the movements of the cirrus clouds in connection with the tropical cyclones, we come now to the discussion of the movement of these clouds in the temperate cyclones. Mr. W. C. Ley has determined from a large number of observations the direction of the cirrus clouds in areas of low pressure in the British Islands, France, Spain, Switzerland, Austria, Turkey, Russia, Denmark, Sweden, and Norway. In obtaining the results he excluded from consideration all depression systems occurring in the colder months whose radius is less than the arbitrary limit of ninety nautical miles, taking as the circumference the exterior of those isobars which form closed curves. He also excluded those which have no circular or nearly circular isobars. Each area of low pressure was divided into sixteen districts, as represented in the diagram shown

* Abercromby, Weather, 1887, 135.

in Fig. 2, the arrow showing the direction of motion. Following is the table of results according to Ferrel's notation: —*

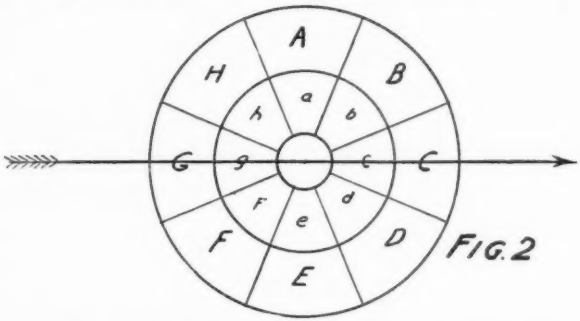


FIG. 2

Districts.	Upper Currents.		Districts.	Upper Currents.	
	No. of Observ.	Mean angle with radius.		No. of Observ.	Mean angle with radius.
A	51	—5°	**a**	58	172°
B	173	163	**b**	104	130
C	226	152	**c**	94	135
D	290	146	**d**	141	102
E	328	124	**e**	135	73
F	199	101	**f**	142	51
G	81	96	**g**	83	90
H	43	99	**h**	46	106

Ferrel discusses and argues from these observations somewhat as follows: It is readily seen that the angles given in this table for the several districts result from an outward cyclonic motion combined with a large progressive motion.

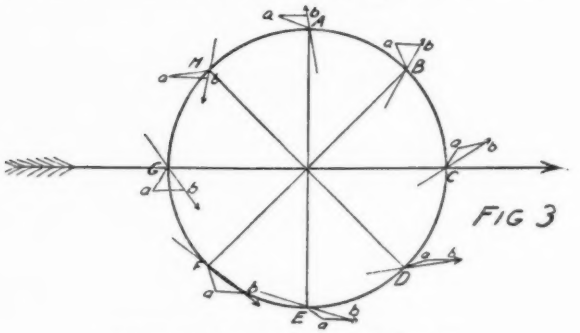


FIG 3

* Quar. Jour. Royal Met. Soc. III. 1877, 437.

Let A, B, C, etc., in Fig. 3,* represent the centres of the several octants in Fig. 2, and let Aa, Ba, Ca, etc., represent the velocities of cyclonic motion, having an outward declination of about 30°, and also a b, represent the velocity of progressive motion of the upper part of the storm in the direction represented by the arrow, and let us suppose that this latter velocity is very nearly equal to that of the cyclonic velocity Aa, Ba, Ca, etc. The resultants will then be represented by Ab, Bb, Cb, etc., and it is evident that the effect of the progressive component is to increase the angles with the radius in the front and to diminish them in the rear. The largest angles with the radius are in the districts B, C, and D, and the smallest those of F, G, and H, and this agrees very nearly with the results given in the table.

Let us now consider also what evidence is furnished by the difference in rate of movement of the cirrus clouds. If there is an upper *outflow* the cirrus clouds ought to move faster in the front and slower in the rear of a storm, but if the upper movement is an *inflowing* one, the reverse will be true; although these observations are deficient in that they do not give us any information as to the relative velocity of the cirrus clouds on the front and rear, yet the fact observed by Ley in regard to octant A shows that there is not an inflow at the top. He says in regard to this district that "the upper current which had previously nearly coincided in direction with the trajectory presently changes, as a rule, to a nearly opposite point, having just before become very slow. In the interval, the cirrus, when visible, which is rarely the case, is sometimes stationary, sometimes moves towards, and sometimes from, the centre of depression, these three instances being nearly equally common, but calms and motions toward the centre predominating."† Now this is what we find ought to be the case when we examine the resultant, in octant A., of outflow and progression. If there were an inflowing motion coupled with the onward motion, the clouds in this section would have a decided movement.

(*To be continued.*)

* Ferrel, Popular Treatise on the Winds, 1889, 310.

† Quart. Jour. Royal Met. Soc. III., 1887, 443.

ARTIFICIAL RAIN.

EDWARD POWERS.

THE article entitled "The Theories of Artificial and Natural Rainfall," by Prof. William Morris Davis, in the March issue of the JOURNAL, though interesting and instructive, is nevertheless a failure in its main object, which is to show that, "independently of the experiments" in Texas, we cannot "look hopefully upon the theory that rain can be artificially produced." He has brought forward nothing which seriously weakens the force of the facts and arguments by which, in "War and the Weather," I support the affirmative of the proposition.

Prof. Davis considers first my facts, and secondly my theories. The more important of these are the facts, for it is wholly upon them that the scheme of artificial rain production rests, my theories being intended simply to show that it may be believed that rain has often been produced by human agency, without such belief necessarily involving a rejection of established physical laws. If he had shown that the probabilities are against the assumption that the rains which I have mentioned as following battles were caused by them, then we should be obliged to admit that he had made good his contention; but it is plain that he has not done so. He adduces only three arguments which have any weight against the conclusiveness of my facts. Two of them I have answered in my book, and my answers have not been shown to be insufficient. One of these arguments is that I do not take account of the comparative frequency of rains in our country. My answer to this is in effect that the frequency of our rains has very little to do with the question, because the greater number of our rains are light rains, while the rains that follow great battles are almost always very heavy. Another argument is that I do not take account of the effect that the weather would have on battles. I have shown in "War and the Weather" the absurdity of this argument even on the supposition that military movements are governed by the prevailing state of the weather. I will add that in the case of naval attacks on

forts and shore batteries I do not have to grant this, but it is in such attacks that I find some of my most striking instances of artificial rain production. The other argument of Prof. Davis to which I have referred is that there is a very considerable variation in the intervals of time between the battles and the rains. This is easily answered. It could not well be otherwise than that, in some cases, the conditions were more favorable for producing rain quickly than in others; and undoubtedly some of the rains would have occurred if there had been no battles, though probably they would not have been so heavy.

In considering my theories, what Prof. Davis has to say might be classed under two heads. Under one we should have allusions to my ignorance, and under the other, assertions which he cannot substantiate. The first are six or seven in number, and however well founded they may be, this, at least, can be said, that I am not so ignorant as not to know that the "studies" and "results" and "advance" of which I am so illy informed are mostly theoretical and that meteorology is not an exact science. I will remark, also, that I have sufficient confidence in my own common-sense to assert that some of the assumptions that are at the foundation of this "advance" are false and absurd. I have, indeed, in the book to which he refers, shown where he has himself given his adhesion to false assumptions; and I have no complaint to make that he should retaliate by charges of ignorance.

But when he goes a little further, and, by garbling and downright misrepresentation, bases a charge against me of making a "parody of scientific argument," I must enter a protest. The misrepresentation of which I complain is in what he says of my theory of the manner in which concussion "may precipitate vapor from the air." Notwithstanding that he knows, and in one part of his article mentions, that the manner in which I claim that vapor is precipitated from the air is by the mixing of two currents of the atmosphere of different temperatures, he says that I illustrate it by likening the action of concussion upon the atmosphere to a blow given upon one of a series of balls arranged in a line. It is true that I illustrate the action of concussion upon the air in that way, but it is not true that I use the illustration to show how vapor is "precipitated." I have never held that concussion can cause condensation of vapor in that way to an extent

sufficient to precipitate it. Prof. Davis was not candid enough to acknowledge this, nor even to complete his explanation of my theory by explaining what use I have for a condensation that is so limited that it does not produce even clouds, much less raindrops, as its primary effect. And yet this explanation is necessary for a clear understanding of one of the theories I have suggested. The use I have for such a partial condensation is to develop heat in the lower or vapor-bearing current. The use I have for such heat is to destroy the equilibrium of that current and cause it to mix with the cold current above it. When such a process is once commenced the motions of the two currents and the latent heat given out by condensing vapor will cause it to go on at a constantly accelerating rate of progress. In this process the work done by the explosions is like that of the spark that lights a conflagration, — it simply starts it. There can be no question that tremendous energies in the form of latent heat are stored up in the vapor of the atmosphere, and I believe that the influence of the firing in a great battle has but to loosen in a small degree these energies to lead to a process that brings them more and more into activity.

Now, although it may never have been proved that concussion may force adjacent molecules of aqueous vapor together and cause them to unite and thus liberate latent heat, it has been proved that pressure will condense aqueous vapor — and what is concussion but a sudden pressure or blow? Where is the "parody of scientific argument" in supposing that two similar things will produce similar results?

The existence of such a principle was indeed indicated by some of Gen. Dyrenforth's experiments in Texas, as shown by the apparent effect of concussion on clouds already formed. The evidence is found in the report of some of these experiments furnished by Prof. Geo. E. Curtis, the meteorologist of the expedition, to the New York *Independent*. He said, "In successive instances when a dense threatening cloud was overhead, a sharp blast of rackarock or of dynamite was followed by a very noticeable spatter of rain, or, in case it was already sprinkling, the blast was followed by a perceptible increase of the shower, lasting for perhaps a minute. This occurred a sufficient number of times to make it quite probable that the relation was that of cause and effect."

To this may be added the fact that battles sometimes apparently cause fogs, in which case we may suppose the force of the explosions to be expended on the surface air, producing a visible effect. But when this force is expended on a vapor-laden current and produces rain, it is not necessary to suppose that the primary effect is visible — the clouds and rain being a secondary effect.

Prof. Davis says: "it is certainly not creditable to Congressional action to undertake experiments upon the artificial production of rain, in our present knowledge of meteorology," thus acknowledging that his knowledge of meteorology is not perfect; and yet throughout his article he makes assertions which are virtually a claim to perfect knowledge of everything pertaining to the circulation of the atmosphere and to rain production. There are only two or three of these that I care particularly to notice. He says that it is out of the question that vapor gathered by the southeast trade-winds should be brought here to form rain, and, by implication, he denies my assertion that it is not the dampness of the lower air that makes our rains, but the rains that make the dampness. It is not necessary to accept Maury's theory of the circulation of the atmosphere in all its details in order to believe that the vapor that forms most of our rains comes from the tropical portion of the Pacific Ocean. If Prof. Davis denies this, it is for him to show where such vapor actually does come from. It is as plain as anything could be made by a mathematical demonstration, and that not of the kind that is based on false assumptions, that as much water comes to us from the oceans as goes back to the oceans by our rivers. Any theory of rain production or of the winds that is inconsistent with this fact is necessarily erroneous. A believer in such a theory would be one of those who say "if the facts do not agree with my theory, so much the worse for the facts." No doubt a large portion of the vapor taken up by the trade-winds is condensed in the doldrums, but a sufficient portion of it somehow gets here to prevent our country from being a desert and to keep up the flow of our rivers. I care not how well reasoned a theory may be that teaches otherwise — some essential fact is overlooked or some false assumption is made in forming it. It would not help his case materially if he could show that the water that comes to us from the ocean is evapo-

rated in the temperate zone. The fact would remain that it does not come to us in the lower air. The general motion of this air over the United States is from west to east. But the humid air of the Mississippi valley is separated from the Pacific by a vast stretch of arid country where the air is very dry. Now the vapors from the Pacific are not carried through this dry air — they are carried over it, — and the conclusion is irresistible that they are carried in currents that are more nearly saturated than is the air at the earth's surface. The inference drawn from this is, and it agrees with all observed phenomena, that rain originates in these currents. It is not necessary that we should know whether it is produced by the cold of expansion, or by the mixing of different masses of air, or by the action of some principle as yet undiscovered, before we can utilize the fact claimed that it is within our power to set in motion the forces that lead to it.

Prof. Davis, speaking of the presence of the writer with the rain-making expedition in Texas, says: "It would be interesting to learn whether he regards the experiments there successful in upholding his theory." To this I reply that, though I was with the rain-making party at Midland, I witnessed no experiments that were worthy of the name. My theory, so far as I have observed, has never been tested.

Congress made an appropriation which would have sufficed for one not large experiment, and it was expended in performing several so-called experiments, not one of which was of sufficient magnitude to allow of any certain conclusion to be arrived at. Still, I think — and it was to me a matter of surprise under the circumstances — that some rain was produced that was wholly artificial in its origin. It was not unknown to me that small battles and even heavy artillery skirmishing had often apparently brought rain, but it was new to my observation that such a small amount of force as that which was at any one time expended on the air at Midland should do so. Believing that the rain produced by a battle is caused by a cyclonic movement, and that to set in motion the natural forces that produce this movement requires a large expenditure of force, I did not see, in such experiments as those performed by Gen Dyrenforth at Midland, any adequate cause for the production of rain. That one of them did seem to produce a shower, renders it more plain to me than ever that we are on the right track to a dis-

covery of inestimable value to the world. Whether or not my theory is correct as to the precise manner in which explosions cause rain is a secondary matter. Indeed, in view of the discovery of Mr. Aitken, of Scotland, as to the influence of dust particles in the air, I regard it as by no means impossible that all theories of rain production will yet have to be remodelled. Further support is given to this idea by the fact that none of the common theories of rain production can account satisfactorily for the formation of rain so rapidly as it is sometimes produced in what is called a "cloud burst," nor can the force developed in a tornado be accounted for except by supposing the existence of a principle as yet undiscovered. I am aware that Ferrel has endeavored to account for this force by known principles, but I have shown elsewhere that his theory rests on absurd assumptions, and does not agree with observed facts. If some scientist would go a little further than Aitken has done, and show that aqueous vapor, under certain conditions, condenses under the influence of molecular motion alone and gives up its latent heat, which becomes an active force to produce molar motion, we should have a key which would unlock the mysteries of both artificial and natural rain production.

I am glad to infer from Prof. Davis' use of the word "hopefully" that he would gladly see the practicability of artificial rainfall become an established fact, notwithstanding that he discourages the performance of experiments in the field to that end. But this cannot be said of all the scientists who are opposed to such experiments, and indeed there is an inconsistency in desiring the one and opposing the other. However valuable laboratory experiments may be in the investigation of questions relating to the condensation of vapor, it is plain that no such experiments can determine whether or not explosions will bring rain, because none could be devised that would meet all the conditions, for these conditions are too many and too complicated and too far beyond the present reach of human knowledge. The revolution of the earth on its axis, the sun's heat, the evaporation from the earth and ocean, the circulation of the atmosphere, and the electrical condition of the earth and air are all involved, and it would be utterly impossible for man to duplicate them on any scale whether large or small. And it would seem that any man really desirous for the advancement

of science and for human progress would be glad to have this matter settled in a direct and straightforward way, in view of the fact that such men as the late Rear Admiral L. M. Goldsborough, Gen. Elisha G. Marshall, Gen. Henry W. Benham, Gen. P. V. Hagner, Gen. John. C. Robinson, and many others of the highest intelligence, have expressed a decided belief, from circumstances that have come under their own observation, that battles bring rain.

DELAVAN, WIS., June 4, 1892.

CURRENT NOTES.

ROYAL METEOROLOGICAL SOCIETY.

The usual monthly meeting of this Society was held on Wednesday evening, May 18, at the Institution of Civil Engineers, 25 Great George Street, London, S. W., Dr. C. Theodore Williams, M. A., president, in the chair. Five honorary members were elected, viz.: Mons. A. D'Abbadie, Dr. W. H. von Bezold, Dr. R. Billwiller, Mons. N. Ekholm, and Prof. P. Tacchmi.

The following papers were read: —

"Raindrops," by Mr. E. J. Lowe, F. R. S., F. R. Met. Soc. The author has made over three hundred sketches of raindrops, and has gathered some interesting facts respecting their variation in size, form, and distribution. Sheets of slate in a book form, which could be instantly closed, were employed; these were ruled in inch squares, and after exposure the drops were copied on sheets of paper ruled like the slates. Some drops produce a wet circular spot, whilst others, falling with greater force, have splashes around the drops. The same sized drop varies considerably in the amount of water it contains. The size of the drop ranges from an almost invisible point to that of at least two inches in diameter. Occasionally large drops fall that must be more or less hollow, — as they fail to wet the whole surface inclosed within the drop. Besides the ordinary raindrops, the author exhibited diagrams showing the drops produced by a mist floating along the ground, and also the manner in which snow-flakes, on melting, wet the slates.

"Results of a Comparison of Richard's Anémo-Cinémographe with the Standard Beckley Anemograph at the Kew Observatory," by Mr. G. M. Whipple, B. Sc., F. R. Met. Soc. This instrument is a windmill-vane anemometer, and is formed by six small wings or vanes of aluminium, four inches in diameter, inclined at forty-five degrees, rivetted on very light steel arms, the diameter of which is so calculated that the vane should make exactly one turn for a meter of wind. Its running is always verified by means of a whirling frame fitted up in an experimental room where the air is absolutely calm, and, if necessary, a table of corrections is supplied. The recording part of the apparatus differs entirely from any other anemometer, and is called the Anémo-Cinémographe, and in principle is as follows: The pen, recording on a movable paper, is wound up at a constant rate by means of a conical pendulum acting as a train of wheel links, whilst a second train, driven by the fan, is always tending to force it down to the lower edge of the paper; its position, therefore, is governed by the relative difference in the velocity of the two trains of wheel-work, being at zero when the air is

calm, but at other times it records the rate of the fan in meters per second. The author has made a comparison of this instrument with the Standard Anemometer at the Kew Observatory, and finds that it gives exceedingly good results.

"Levels of the River Vaal, at Kimberley, South Africa, with Remarks on the Rainfall of the Watershed," by Mr. W. B. Tripp, M. Inst. C. E., F. R. Met. Soc. Measurements of the height of the river Vaal have for several years past been made at the Kimberley water-works. These gaugings having been placed at the disposal of the Society, the author has compared them with the rainfall of the watershed. There is a marked period of floods and fluctuations at a comparatively high level from about the end of October to the latter part of April, and a period of quiescence, during which the river steadily falls with very slight fluctuations from about April 19 to Oct. 31. The highest flood, five hundred and twenty-five feet, occurred in 1880, the next highest being five hundred and three feet, on Jan. 24, 1891.

The last meeting of the Society for the present session was held on Wednesday evening, June 15. The following papers were read: —

"English Climatology, 1881–1890," by Mr. F. C. Bayard, F. R. Met. Soc. This is a discussion of the results of the climatological observations made at the Society's stations and printed in the "Meteorological Record" for the ten years 1881–1890. The instruments at these stations have all been verified, and are exposed under similar conditions, the thermometers being mounted in a Stevenson screen with their bulbs four feet above the ground. The stations are regularly inspected and the instruments tested by the assistant secretary. The stations now number about eighty, but there were only fifty-two which had complete results for the ten years in question. The author has discussed the results from these stations and given the monthly and yearly means of temperature, humidity, cloud, and rainfall. His general conclusions are: (1) With respect to mean temperature the sea-coast stations are warm in winter and cool in summer, whilst the inland stations are cold in winter and hot in summer. (2) At all stations the maximum temperature occurs in July or August, and the minimum in December or January. (3) Relative humidity is lowest at the sea-coast stations and highest at the inland ones. (4) The southwestern district seems the most cloudy in winter, spring, and autumn, and the southern district the least cloudy in the summer months, and the sea-coast stations are, as a rule, less cloudy than the inland ones. (5) Rainfall is smallest in April and, as a rule, greatest in November, and it increases from east to west.

"The mean temperature of the air on each day of the year at the Royal Observatory, Greenwich, on the average of the fifty years, 1841 to 1890," by Mr. W. Ellis, F. R. A. S. The values given in this paper are derived from eye observations from 1841 to 1848, and from the photographic records from 1849 to 1890. The mean annual temperature is 49.5°. The lowest winter temperature, 37.2°, occurs on Jan. 12, and the highest summer temperature, 63.8°, on July 15. The average temperature of the year is reached in spring on May 2, and in autumn on Oct. 18. The

interval during which the temperature is above the average is one hundred and sixty-nine days, the interval during which it is below the average being one hundred and ninety-six days.

Artificial Rain. — Mr. R. G. Dyrenforth's official report on the artificial rain experiments, which he directed in Texas during the past summer, has just been printed for the United States Senate (Fifty-second Congress, 1st Session, Senate Ex. Doc. No. 45). The pamphlet adds very little to what is already known of that sensational expedition, and the whole subject has received so much attention lately in the JOURNAL that it is unnecessary to do more than refer to the main points in this report.

After a few words as to the history and origin of the schemes for producing rain by artificial means, Mr. Dyrenforth says: "Without any theory or theories on the subject myself, I understood your appointment to mean that I was to consider and formulate, and adopt or devise the most practical and reasonable means to ascertain whether violent and sudden motion or concussions, produced upon the air by explosions, can have any effect toward the production of rainfall." The account of the apparatus and of the operations at Midland is minute, and several cuts are given,— of the party, the ranch, the balloons, etc. One of the principal tests was that of Aug. 25, of which a careful account is given. The morning was clear and, according to the ranchmen, the weather was "settled dry." A strong southerly wind made operations with the balloons extremely difficult, and at sundown ground explosions were begun, and continued throughout the evening. To quote Mr. Dyrenforth: "The firing ceased at about 11 P. M., the atmosphere at that time being very clear, and as dry as I have ever observed it. At about three o'clock on the following morning, Aug. 25, I was awakened by violent thunder, which was accompanied by vivid lightning, and a heavy rainstorm was seen to the north,— that is, in the direction toward which the surface wind had been steadily blowing during the firing, and hence the direction in which the shocks of the explosion were chiefly carried. The storm extended northwest. The wind was directly north, and the clouds approached slowly during the next two hours, until shortly before six o'clock A. M. a heavy rain could be seen falling over the north pastures of the ranch. The rain continued falling heavily over the entire north half of the ranch for about two hours. Only the edge of the clouds passed over the ranch-house, however, so that the rain there was slight; but Mr. Rannells, manager of the ranch, an experienced ranchman, and others of the party, and I, estimated the rainfall to be not less than one inch and probably as much as an inch and a half on the north pastures less than two miles from the house. While the thin edge of the cloud was overhead a few charges of dynamite were fired near the ranch-house. A few moments after the first explosion the first overhead rain began, and after each subsequent explosion rain could be seen falling from the clouds overhead in what appeared to be a heavy shower, but the air was still so dry that at first no rain and afterward only a sprinkle reached the ground. After each explosion the quantity of rainfall increased. . . . I have seen since that on the map of the Weather Bureau of Aug. 25, 8 P. M., the forecast to 8 P. M. of Aug. 26 predicted

local showers on the extreme southeast coast and in the northwest (I do not know whether this means the extreme northwest or anywhere north and west of the centre of the State); but from what precedes, it appears that while I was in Texas showers were several times predicted for the region, and did not occur at Midland and vicinity when there were no explosions, and that when showers were not predicted for the region, and there were explosions, showers occurred, so I do not consider it conclusive that because in a general way showers were predicted for the northwest region, and we got a rain after firing, consequently the firing must appear as having been superfluous. Besides, what came was not a shower, it was a heavy rain, estimated for the north pastures of the 'C' ranch and part of the Slaughter ranch at one and one half inches."

In concluding his report the writer says: "I particularly invite your consideration of the following phenomena believed to have been observed: —

"(1) The hot and dry surface stratum of air in arid regions, exerting a repellant action upon any superior bodies or strata of air.

"(2) The visible dissolving of clouds, showing the conversion or reconversion of moisture into vapor upon contact of the clouds with the dry and warmer air of the surface stratum, the appearance being particularly striking when occurring when clouds are moving towards the observer.

"(3) The visible precipitation from a cloud, without the precipitation reaching the ground.

"(4) The greater rapidity of the surface currents as compared with the higher currents, and the difference in direction of these currents from the surface currents and from each other at different altitudes.

"(5) The mechanical effect of some of the explosions manifest in the whirling ring of ascending smoke attended by the peculiar moaning sound.

"(6) The great force of the waves resulting from explosions, and the return wave resulting from contact of the explosion wave with a cloud.

"(7) The precipitation from a moist cloud near by, from the blow of an explosion.

"(8) The appearance of heavy cloud-formation, succeeding explosions, in the direction towards which the wind is blowing at the time of the explosions.

"(9) The tendency of cloud-formation to develop at places on the horizon of the field of explosion, and the appearance of rain at these points gradually extending to the centre, where it rained last when it rained at all."

Mr. Dyrenforth's deductions are as follows: "The few experiments which have been made do not furnish sufficient data from which to form definite conclusions, or evidence upon which to uphold or condemn the theories of the artificial production or increase of rainfall by concussion. Experiments extending over a period of only a few months can scarcely be sufficient. It is only by a large number of tests, with accurate noting of conditions and occurrences, that definite conclusions can be reached; and if then it be ascertained to be a certainty that rainfall will be induced by explosions, that such production of rainfall can be reduced to an art, so as to effect precipitation at a predetermined place. What has been done so

far is altogether preliminary ; but, with the benefit of the experience gained, I hope that the subject will be pursued."

We have been disappointed but not surprised to find no narrative account of the experiments by Mr. George E. Curtis, who went with the expedition as meteorologist. Mr. Curtis's report is simply a tabular statement of the tri-daily observations which he took while at Midland, during the time from Aug. 12 to 24. In "Nature," Vol. 44, 1891, page 594, Mr. Curtis gave a short account of the explosions and their effects which he witnessed while with Mr. Dyrenforth at Midland. In this paper he says: "On Aug. 16, 17, 18, and 20 cloudy weather very largely prevailed, and numerous thunderstorms were seen on the horizon that did not visit the ranch. On each of these days blasts of rackarock and of dynamite were fired while heavy cumulus or dense storm-clouds were in the field. In several instances when a dense threatening cloud was overhead a sharp detonating explosion of rackarock or of dynamite was followed at an interval of thirty to forty seconds by a spatter of rain, or, if it was already sprinkling, the blast was followed by a very noticeable increase of the drops. This interesting result occurred a sufficient number of times to indicate that the phenomenon was a real effect of the explosions. On none of these days, however, was the amount of the rainfall appreciable, except on the 18th, when it was two hundredths (0.02) of an inch. The 18th opened cloudy, and old settlers predicted rain for the afternoon, whether the experiments should be made or not. To what extent, therefore, the explosions that were made were influential in producing the 0.02 inch that fell is obviously very difficult to determine, and as an evidence of the efficacy of the explosions it is practically valueless.

"The next explosions were on the evening of Aug. 21, when one hundred and fifty-six pounds of rackarock were fired in fourteen blasts. During the night a genuine norther came on, the wind blew from the north, the barograph curve rose rapidly, the temperature fell rapidly, and during the next forenoon a fine mist prevailed. This change of weather was quite extraordinary and unexpected, and with its accompanying mist was attributed to the heavy firing of the evening previous ; but the norther had been on its way for several days, and the fine mist was evidently due to the uplifting by the cold north wind of the warm moist air of the plains. At numerous points in the State where the air was more humid a heavy rainfall occurred.

"The last experiment, which in magnitude was the greatest of all, took place on the evening of Aug. 25, after the writer had departed. The conditions were thought to be extremely unfavorable for rain, and the party was advised to wait for a more propitious occasion. The firing, however, was carried on until 11 P. M., when the party retired for the night. It is reported that "at 3 A. M. the heavy rolling of thunder disturbed the sleepers, heavy banks of clouds were seen advancing, almost constantly lighted by most brilliant lightning. An hour later the rain began to fall in torrents on the ranch, and did not cease till 8 A. M." Unfortunately, records of the amount of rainfall have not yet been received, but I am informed by a gentleman who was present that "it was nothing but a sprinkle." Further

light is thrown on this rainfall by the weather map for 8 P. M., eastern time, of Aug. 25. Rainfall is shown in New Mexico to the northwest of Midland, Texas, and the forecast officer made the following prediction: "For eastern Texas, generally fair, except local showers on the extreme southeast coast and the northwest." Here we have an official prediction made in Washington City of probable showers over the district in which the experimenters were operating, and for the very night in which the thunderstorm followed the last of the explosions to produce rain.

"In view of these facts, it is scarcely necessary for me to state that these experiments have not afforded any scientific standing to the theory that rain-storms can be produced by concussions. But, if the adherents of the theory maintain 'that no experiment has been tried that is worthy of the name, and that no results ought to be looked for,' it will be difficult to take the opposite ground."

Meteorological Education in Europe. — Through the kindness of the Chief of the Weather Bureau we are permitted to publish the following translation of portions of a letter received by him from Mr. Hepites, the director of the Roumanian Weather Service: —

"In conformity with your idea, I will summarize for you the answers received in answer to my circular. They relate to Austria, Russia, Bavaria, Saxony, the Grand Duchy of Baden, Alsace-Lorraine, Spain, Holland, Denmark, Sweden, Norway, England, and Italy.

"1. In Austria there is no special chair for meteorology. It is, however, taught by the professors of physics at the universities of Vienna, Prague, and Innsbruck. Dr. Hann teaches meteorology and terrestrial magnetism at the University of Vienna. In the same city, Dr. Liznar teaches meteorology as *privat docent*, at the Technical High School. At Innsbruck there is a special chair for cosmic physics, the titular professor of which, Dr. Pernter, occupies himself with meteorology. At Prague Dr. Augustin is *privat docent* for meteorology. Climatology is taught in Austria in all the universities by the professors of geography. At the Nautical Academy of Trieste there is a chair of meteorology and oceanography (M. Ed. Mazelle).

"2. Bavaria has three universities; only the one at Munich possesses a chair of forest meteorology (Prof. Ebermayer). At the School of Technology at Munich there is a chair of agricultural meteorology (Prof. Wollny), and another for universal geography (Prof. Gunther). The latter teaches climatology and terrestrial magnetism. Prof. Lang and Dr. Erk, as *privat docent*, give lessons in practical and theoretical meteorology at the University and at the Technical School.

"3. In Saxony, meteorology is not taught, either at the University of Leipsic, or at the Superior Technical School of Dresden, or at the Academy of Freiburg.

"4. In the universities of the Grand Duchy of Baden (Heidelberg, Freiburg, Carlsruhe) there is no chair for meteorology. Dr. Schultheiss teaches, as *privat docent* at the Polytechnical School of Carlsruhe, climatol-

ogy and synoptical meteorology. In this school, meteorology forms a separate course.

"5. In Alsace-Lorraine there is no special chair for meteorology. Dr. Hergesell, however, gives some lessons in meteorology at the University of Strasburg every semester. Dr. Gerland, professor of geography at the same university, also treats certain meteorological questions.

"6. In Spain there is a special chair of meteorology. At Madrid, at the University, there is a chair of physical geography, where the subjects are treated from a point of view mathematical rather than physical. At the School of 'Ponts et Chaussées,' for the classes on maritime construction, and at the schools for engineers of forestry and agriculture, some lessons in meteorology are given.

"7. In the four universities in Holland there is no chair for meteorology; this course of study is intrusted to the ordinary prefessors of physics; they do nothing with it. Since the death of Buys-Ballot, Mr. Snellen is the *privat docent* for meteorology at the University of Utrecht. At the School of Agriculture at Wageningen meteorology forms a separate course. The elements of meteorology are taught in the secondary schools.

"8. In Denmark there is no special chair for meteorology. At Copenhagen the professor of geography at the university teaches climatology. Meteorology is also taught at the Naval School and at all the schools of navigation.

"9. At the university of Upsala meteorology does not form an obligatory course; nevertheless, M. Hildebrandsson, who is a member of the Faculty of Sciences, gives annually twenty-five lessons in meteorology. There are always pupils who follow these courses and who work at the meteorological observatory.

"10. In Norway, at the university of Christiania, Mr. Mohn has a special chair for meteorology. There are also minor courses of meteorology at the schools of navigation and at the Naval Academy for the officers of the navy.

"11. In Russia, in the universities, meteorology is included in the chairs of physics and of physical geography. In several universities meteorology is taught by specialists, — St. Petersburg, Kharkow, Odessa, Kiew. The professorships at Moscow and Dorpat are at present vacant. Meteorology is also taught at the Agricultural and Forestal Institute of St. Petersburg, at the Agricultural Institute of Petrowsky, near Moscow, and at the Naval Academy.

"12. In England there are no special chairs for meteorology; it may be that among the professors of physics there are some who teach it.

"13. In Italy there is no university course where meteorology is officially taught or where this branch is obligatory on the pupils. This subject is included in the courses of geography, physical geography, physics, and hygiene. At Naples there is, however, a course of meteorological terrestrial physics, conducted by Prof. L. Palmieri. For the past few years there have been *privat docents* at the universities of Genoa, Pavia, and Padua, who gives lectures on meteorology. At the universities of Palermo, Pisa, and

Padua there are chairs of physical geography. At Padua there is a *privat docent* who teaches climatology.

"This is all the information that I have obtained up to the present time in answer to my circular of the 23d of October, 1891. In case I receive any other answers on this subject I will send them to you immediately. I can add a few words more on instruction in meteorology. In France there is, to the best of my knowledge, only a single special chair of meteorology, — it is that of the Faculty of Sciences, at Nancy. The professor, Mr. Ch. Millot, has already published his lectures. At the Agricultural Institute of Paris, Mr. Duclaux is very earnest in advocating meteorology. The observatory of the Parc St. Maur, under the direction of Mr. Renou, forms one of the annexes of the Sorbonne for meteorological investigations. At the Sorbonne the professors of physics do not occupy themselves with meteorology. The universities of Belgium have no chairs specially for meteorology, and the professors of physics do not teach this branch of science. The universities of Roumania (Bucharest, Jassy) have no chairs either for meteorology or for physical geography, and the professors of physics do not occupy themselves with it. At the central School of Agriculture of Herestreu (Bucharest) there is a chair of physics, meteorology, and mineralogy; meteorology, however, is scarcely taught at all. In Bulgaria there is no university."

The Climate of Death Valley, Cal. — Some interesting notes in connection with Death Valley, Cal., are found in an article by Mr. John R. Spears, in the May number of Goldthwaite's "Geographical Magazine," originally printed in the New York *Sun*. The valley is guarded on the west by a lofty and precipitous mountain range, and four other ranges and four valleys lie between it and the Pacific, thus forming a most successful barrier against moisture. Indeed the percentage of moisture is said to be at times less than one per cent of saturation. This excessive dryness has curious effects on pieces of furniture, warping them into many fantastic shapes. Meat killed at night and cooked at six in the morning is often spoiled at nine. The thermometer is said to have repeatedly registered one hundred and thirty degrees in the shade, and one reading of one hundred and thirty-seven degrees is reported under the veranda on the north side of a house in the valley. During the winter, on the other hand, the temperature is said sometimes to sink to more than fifty degrees below zero. The rainfall is usually in "cloud-bursts," which appear as black clouds, growing very rapidly, and suddenly precipitating floods of water, which fill the dry gulches and stream beds almost in an instant, sending torrents of water down into the valley below. These torrents rush down with tremendous force, and they are often ten feet or more in height at their front, advancing as a wall of water.

A characteristic occurrence among the many meteorological phenomena of Death Valley is the duststorm, which often blows with fury through the valley. Mr. Spear thus describes a duststorm which he witnessed during his stay there: "The whole vast space between the ranges was filled with smoky billows, ragged and torn, and tossed about and rising up until the

foothills and half the heights themselves were covered. Sharp squalls plunged down the cañons and gulches, and there gathering the dusty forms in their arms, went whirling away in gigantic waltzes. It is no wonder that the Arabs of this desert country believe in witches and supernatural powers in the air. . . . At times these lofty whirligigs take on more substantial form; become, in fact, like the waterspouts at sea, real sand spouts. The desert men then call them sand augers. It is a marvellous spectacle when a sand auger travels down the valley, particularly if its course be along one side of the valley where the dusty fog is not so dense as elsewhere. Astonishingly slender in form, it rises, writhing and twisting, sometimes a mile in the air. With a faint puff or cloud at the top and a slight spread at the base, away it goes, sagging and swaying hither and thither, its sinuous grace fascinating the eye until somehow it all unexpectedly vanishes. I saw two such augers. Both were more than two thousand feet high. Neither journeyed a mile, but when they faded away there was no sign of a falling cloud or a thickening of the dust in the air where they had been. They simply disappeared as I was looking at them. . . . The sand storms commonly last for three days. The one I saw lasted but two. In the afternoon of the first day the speed of the wind increased rapidly until it was probably travelling at times as high as fifty miles an hour, perhaps more. At this time the gusts picked up pebbles as well as sand and dust. The air near the earth was full of flying missiles."

The effect of the winds on the formation of sand dunes is seen on the northern side of the Amargosa Valley, to the east of Death Valley. Here a curious feature is noted in the effect of a row of black lava peaks, five hundred to seven hundred feet high, which runs directly across the path of the dunes. The onward movement of the dunes has carried them completely over the lava ridges, and some of the sand now lies on the leeward side.

Thunderstorms in the Eastern Alps. — In the "Meteorologische Zeit-Schrift" for May Dr. Karl Prohaska gives an account of a series of violent thunderstorms which occurred in the Eastern Alps on Aug. 25 and 26, 1890, illustrated by weather maps and charts showing the distribution of pressure at an altitude of twenty-five hundred meters over the district. The conditions which bring about such thunderstorms in this region are described as follows: A deep and somewhat long-enduring depression on the southern side of the Alps produces on their northwestern and northern sides an ascending current of air, accompanied by cold and rain, while on the eastern and southeastern sides the high temperatures continue with slight changes. The result of this is that the low pressure on the southeastern side changes to a high pressure at greater altitudes, while on the other hand the centre of low pressure lies over Switzerland and the Tyrol at the same altitude. Thus diverging currents arise over the Alpine district in the upper and lower strata of air, which cause the formation of thunderstorms. When the depression finally moves off from Upper Italy to the northeast, then the lower northwest wind has full play on the southeastern and eastern margin of the Alps, and brings a marked fall of temperature in this region, if the high temperature has remained there until the disappearance of the depression.

BIBLIOGRAPHICAL NOTE.

Report of the Chief Signal Officer for 1891 :—

Gen. A. W. Greely's last annual report on the meteorological work of the Signal Corps has recently been printed.*

This report contains the usual amount of valuable information and data. The percentage of verification of temperature and weather forecasts combined was, in 1889, 81.0; in 1890, 82.6, and in 1891, 83.5. Long-time forecasts of weather and temperature, which have been issued at the discretion of the forecast official, have had successful percentages of 84.1 for forty-eight hours, and 87.1 for seventy-two hours, which is an improvement over similar forecasts for 1889, 1890, of 2.5 per cent for the forty-eight-hour predictions and 5.7 per cent for those of seventy-two hours. The number of voluntary observers in 1891 was 1,916. It is gratifying to learn that it is hoped that the bibliography or meteorology will appear in print during the next few years.

Among the appendices to this report the following may be mentioned: Weather Forecasting at the Signal Office, June 30, 1891, by Prof. H. A. Hazen; Report of Forecasts on Cold Waves, and of the Professor in Charge of the River and Flood Division, by Prof. T. Russell; Report of the Officer in Charge of the Stations Division, containing a valuable Synoptical Sketch of the Progress of Meteorology in the United States, by Lieut. W. A. Glassford; Farewell Order of the Chief Signal Officer; Report of Assistant Professor in Charge of the Instrument Division, by Assistant Professor C. F. Marvin; Report of Bibliographer and Librarian, containing a list of publications of the United States Signal Service from 1861 to July 1, 1891, by Mr. O. L. Fassig; International Pressure and Storm Charts, by Gen. A. W. Greely, with twenty-five charts. Charts 1 to 12 indicate graphically for each month of the year the mean barometric pressure and prevailing winds for noon, Greenwich time, as determined from the international simultaneous meteorological observations from 1878 to 1887. Charts 13 to 24 show the mean monthly barometric changes over the northern hemisphere. Chart 25 shows the storm frequency of the northern hemisphere as deducted from the international simultaneous observations.

* Fifty-second Congress, 1st Session. House of Representatives, Ex. Doc. I., part 2. Washington, Government Printing Office, 1892. Pages 777, 25 charts.

PUBLICATIONS RECEIVED.

"The American Journal of Science," New Haven, Conn., James D. and Edward S. Dana, editors, Vol. XLIII., June, 1892. This number contains an article by L. A. Bauer on "Wilde's Explication of the Secular Variation Phenomenon of Terrestrial Magnetism.

"Astronomy and Astro-Physics," Northfield, Minn., June, 1892. This number presents several interesting astronomical articles, together with numerous notes on current celestial phenomena and other matters in connection with astro-physics.

"Meteorologische Zeitschrift," Wien, redigirt von Dr. J. Hann and Dr. G. Hellmann, May, 1892. 8vo. This issue contains an Account of the Thunderstorms in the Alps on Aug. 25-26, 1890, by Dr. Karl Prohaska; Dr. Hellmann's Results on the Exposure of Rain-gauges in Berlin from 1885 to 1891, reference to which has already been made in this JOURNAL for June; remarks on the Observation of Cirrus Clouds by C. Kassner, and other notes on matters of interest.

"Quarterly Journal of the Royal Meteorological Society," London, edited by a Committee of the Council, Vol. XVIII. No. 82, April, 1892. 8vo. The principal articles are the following: "Evaporation and Condensation," by Baldwin Latham, M. Inst. C. E., F. G. S.; "Report on the Phenological Observations for 1891," by Edward Mawley, F. R. Met. Soc., F. R. H. S.; "The Untenability of the Atmospheric Hypothesis of Epidemics," by Hon. F. A. R. Russell, M. A., F. R. Met. Soc.

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"Notes on the Climate and Meteorology of Death Valley, California," by Mark W. Harrington, Chief of Weather Bureau, U. S. Department of Agriculture, Weather Bureau. Bulletin No. I, Washington, Weather Bureau 1892. 8vo. fifty pages.

"Wreck Chart of the Great Lakes, showing the location of Wrecks occasioned through Founderings, Gales of Wind, Fogs and General Stormy Conditions from 1886 to 1891." U. S. Department of Agriculture, Weather Bureau, Washington, D. C., 1892.